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Fixed ball joint with rotated track cross-sections

Description

The invention relates to constant velocity joints in the form
of fixed joints with the following characteristics:
an outer joint part which comprises a longitudinal axis $L12$ as
well as an attaching end and an aperture end positioned axi-
ally opposite one another, and which is provided with outer
ball tracks;
an inner joint part which comprises a longitudinal axis $L13$
and attaching means for a shaft pointing towards the aperture
end of the outer joint part and which is provided with inner
ball tracks;
the outer ball tracks and the inner ball tracks form pairs of
tracks;
the pairs of tracks each accommodate a torque transmitting
ball;
each two adjoining pairs of tracks comprise outer ball tracks
whose centre lines are positioned in planes $E1$, $E2$ which ex-
tend substantially parallel relative to one another, as well
as inner ball tracks whose centre lines are positioned in pla-
nes $E1'$, $E2'$ which extend substantially parallel relative to
one another;
an annular ball cage is positioned between the outer joint
part and the inner joint part and comprises circumferentially
distributed cage windows which each accommodate the torque
transmitting balls of two adjoining pairs of tracks;
in an aligned joint, the centres K_1, K_2 of the balls are held

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by the ball cage in the joint centre plane EM and when the joint is articulated, they are guided onto the angle-bisecting plane between the longitudinal axes L12, L13.

Joints of this type are known from DE 44 40 285 C1 for example. In these joints, torque can be transmitted in the torque direction by half the balls only.

Joints of a similar type are known from DE 100 33 491 A1 wherein the cross-section of the outer ball tracks and of the inner ball tracks is defined by circular arches, with the respective axis of symmetry of the ball track cross-sections being positioned in those planes which contain the track centre lines. Under torque conditions, depending on the torque transmitting direction, this leads to disadvantageous load conditions at the track edges.

It is the object of the present invention to propose joints of said type which, under torque load, comprise the most advantageous load conditions independently of the torque transmitting direction.

The objective is achieved by providing joints of said type wherein the track cross-sections of the outer ball tracks and of the inner ball tracks of each pair of tracks are symmetrical relative to axes of symmetry ES_1, ES_2 which, together with the planes E1, E2, E1′, E2′, form identically sized angles φ_1, φ_2 opening in opposite directions and each comprise a common point M, M′. Herein it is proposed that the angles φ_1, φ_2 range from 0.8 to 1.3 φ_0, wherein $2\varphi_0$ constitutes the centre angle in an aligned joint between radial rays RS1, RS2 from the longitudinal axes L12, L13 through the ball centres K1, K2 of the balls of two adjoining pairs of tracks. The significance of this measure can be explained as follows: If φ_1, φ_2

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equal φ_0, then the track cross-sections of the outer ball tracks and of the inner ball tracks of each pair of tracks are symmetrical relative to radial rays RS1, RS2 from the longitudinal axes through the ball centres K1, K2 of the torque transmitting balls of the pair of tracks. If φ_1, φ_2 are not equal to φ_0, then the track cross-sections of the outer ball tracks and of the inner ball tracks of each pair of tracks are symmetrical relative to the straight lines PS_1, PS_2 which are positioned in the cross-sectional plane, which are parallel to the radial rays RS1, RS2 and which intersect one another in a common point M' at a distance from the longitudinal axes L12, L13.

Therefore, in fixed joints whose balls are guided in ball tracks extending in pairs in substantially parallel planes E1, E2, E1', E2' – wherein, in order to increase the load bearing capacity, two balls each are received in a cage window – it is ensured that the introduction of force into the ball tracks is improved and guarantees substantially uniform conditions independently of the torque transmitting direction. This is achieved by the symmetric design of the track cross-sections of each pair of tracks relative to the radial rays RS1, RS2 from the longitudinal axis L12, L13 through the ball centres K1, K2 and relative to the straight lines PS1, PS2 which extend parallel to such radial rays. Slight deviations from the strict symmetry relative to the individual radial rays RS1, RS2 are permissible and possibly advantageous, more particularly in those cases where the ball tracks are produced with tools whose movements are to take place on defined planes, with the tool axes preferably being kept parallel relative to one another.

According to a first basic embodiment it is proposed that the track centre lines M22 of the outer ball tracks and the track

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centre lines M23 of the inner ball tracks are positioned in planes E1, E2 which extend parallel relative to one another and parallel to the longitudinal axes L12, L13 of the joint and extend through the ball centres of the balls of two ad-joining pairs of tracks.

It is proposed that the joint is provided in the form of a twin ball joint, wherein the opening angles α_1, α_2 between the tangents at the base lines of two adjoining pairs of tracks in an aligned joint in the joint centre plane EM, in each case, open in the same direction, more particularly towards the at-taching end of the outer joint part.

According to a second basic embodiment it is proposed that the joint is provided in the form of a counter track joint, whe-rein the opening angles α_1, α_2 between the tangents at the base lines of two adjoining pairs of tracks in an aligned joint in the joint centre plane EM open in opposite directions. More particularly, it is proposed that the balls of two adjoining pairs of tracks in an aligned joint are positioned on diffe-rent pitch circle radii.

According to a further basic alternative embodiment it is pro-posed that the track centre lines $M22_1$, $M22_2$ of the outer ball tracks extend in planes E1, E2 which extend parallel relative to one another and through the ball centres of the balls of two adjoining pairs of tracks and which comprise identical perpendicular distances from the joint centre M, while forming intersection angles γ_0 with parallel lines relative to the lon-gitudinal axes L12, L13 and that track centre lines $M23_1$, $M23_2$ of the outer ball tracks extend in planes E1', E2' which ex-tend parallel relative to one another and through the ball centres of the balls of two adjoining pairs of tracks and which comprise identical perpendicular distances from the

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joint centre M, while forming intersection angles γ_0' with parallel lines relative to the longitudinal axes L12, L13. The angles γ_0 and γ_0' are identical in size and open in opposite directions, so that there is obtained an intersection angle angles $\gamma_0 + \gamma_0'$ between the planes E1, E2 of the outer tracks and the planes E1', E2' of the inner tracks.

In contrast to the initially mentioned embodiment wherein the spatial control angle at the balls changes slightly as a function of the direction of the introduction of torque, it is possible with the above embodiment to compensate for the dependence of the spatial control angles ε_0, ε_0' at the balls on the torque transmitting direction. More particularly, it is proposed that the intersection angles γ_0 , γ_0' should be selected to be such that the spatial control angles of the ball tracks are identical in size both in the case of a torque Kr_0 rotating clockwise or a torque Kl_0 rotating anti-clockwise.

Furthermore, it is proposed that with a centre angle $2\varphi_0$ between the radial rays RS1, RS2 through the ball centres of the balls of two adjoining pairs of tracks, the angle of intersection γ_0 is calculated in accordance with the equation $\gamma_0 = \varepsilon_0 \times \tan\varphi_0$ to ensure that the spatial control angles are identical in size regardless of whether the load on the joint rotates to clockwise or anticlockwise.

If the track centre lines are positioned in the axis-parallel planes E1, E2, there are obtained different spatial control angles for clockwise and anti-clockwise torque rotations, which is due to the fact that the contact angles δ for torque loads rotating clockwise and anti-clockwise are symmetrical relative to the radial ray RS. The spatial control angles for loads rotating clockwise and anti-clockwise are

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$$Kr_0 = \varepsilon_0 \times \cos(\delta + \varphi)$$

$$Kl_0 = \varepsilon_0 \times \cos(\delta - \varphi_0)$$

Because of the +/- φ_0 influence, they are clearly different.

By rotating the planes E1, E2 around a normal axis around the intersection angle γ_0, it is possible to ensure that spatial control angles Kr_0, Kl_0 become identical. This is the case for the condition $\gamma_0 = \varepsilon_0 \times \tan\varphi_0$.

According to a first embodiment of the track cross-sections it is proposed that the track cross-sections of the outer ball tracks and of the inner ball tracks are formed by circular portions whose centres of curvature are positioned at a distance from one another on the respective radial ray RS1, RS2 and, respectively, on the straight lines PS1,PS2 extending parallel thereto and whose radius of curvature is greater than the ball radius and which generate contact with the balls in one point only which, in a torque-free condition, is positioned in the track base.

Figure 1 shows an inventive joint having the characteristics in accordance with the invention
   a) in half a cross-section according to sectional line C-C of Figure 1b
   b) in an offset longitudinal section according to sectional line B-B of Figure 1a.

Figure 2 shows an inventive joint in the form of a twin ball joint
   a) in an axial view
   b) in a longitudinal section along the sectional planes A-A, B-B of Figure 2a.

Figure 3 shows an inventive joint in the form of a counter track joint

    a) in a cross-section through the centre plane EM

    b) in a longitudinal section according to the sectional plane A-A in Figure 3a

    c) in a cross-section according to sectional plane B-B in Figure 3a.

Figure 4 shows an inventive joint in the form of counter track joint in an alternative embodiment

    a) in a cross-section through the centre plane EM

    b) in a longitudinal section according to the sectional line A-A of Figure 4a.

Figure 5 shows a partial cross-section through an inventive joint in a first embodiment of the ball track cross-section according to sectional line C-C in Figure 1b.

Figure 6 shows a partial cross-section through an inventive joint in a second embodiment of the ball track cross-section according to sectional line C-C of Figure 1b.

Figure 7 shows the joint according to Figure 1 in a modified embodiment

    a) in half a cross-section according to sectional line C-C of Figure 7b

    b) in an offset longitudinal section according to sectional line B-B of Figure 7a.

Figure 8 shows a partial cross-section through an inventive joint with reference to Figure 7.

Figure 9 shows angle conditions according to the joint accord-

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ing to Figure 2 in an illustration with vertical exaggeration.

The two illustrations of Figure 1 will be described jointly below. Figure 1 shows a constant velocity fixed joint 11 which comprises an outer joint part 12, an inner joint part 13, torque transmitting balls 14 and a ball cage 16. Two balls 14_1, 14_2 each are accommodated in a common cage window 17 of the ball cage. The balls are held in outer ball tracks 22_1, 22_2 and inner ball tracks 23_1, 23_2, wherein the ball tracks of adjoining balls 14_1, 14_2 form pairs of tracks 22_1, 23_1, 22_2, 23_2. RS1 and RS2 refer to radial rays from the longitudinal axes L12, L13 through the centres K1, K2 of the balls 14_1, 14_2. S1 and S2 refer to the sectional lines of planes E1, E2, E1', E2' in which there are positioned the centre lines of the ball tracks, with the sectional plane C-C which approximately can be regarded as the cross-sectional plane through the joint. In these planes E1, E2, E1', E2' there are positioned the centre lines of the ball tracks. These can be provided in the form of planes extending parallel to the longitudinal axes L12, L13 or as planes which form an angle of intersection with the longitudinal axes L12, L13 and are parallel to one another in pairs. The ball tracks extend symmetrically relative to axes of symmetry ES1, ES2 which, together with the radial planes R1, R2, form identically sized angles φ_{01}, φ_{02} opening in opposite directions and which, in the present case, correspond to the radial rays RS1, RS2.

φ_{01}, φ_{02} is given as half the centre angle between the radial rays RS1, RS2 through the centres of the balls 14_1, 14_2 with reference to the longitudinal axes L12, L13 and, respectively, half the opening angle between the two radial rays RS1, RS2.

The design of the ball tracks is not given in greater detail, but it should be such that, if the torque on the inner joint

part rotates clockwise, the pair of forces FR acts at an angle
δ with reference to the radial ray RS on the ball, and if the
torque on the inner joint part rotates anticlockwise, the pair
of forces FL acts on the ball at the same angle δ with refer-
ence to the radial ray RS. The points of impact of the forces
FR, FL represent the contact points of the ball tracks with
the ball under torque.

Figure 1b, in addition, shows the ball tracks 22_2, 22_3 with
the track centre lines M22, M23, as well as the tangents T22,
T23 at the ball track base lines in the plane C-C. Tangents
T22', T23' at the track centre lines M22, M23 extend parallel
to said tangents T22, T23 at the track base lines and are po-
sitioned in planes which, according to the above, can be posi-
tioned parallel to the longitudinal axes L12, L13 or at an an-
gle relative to the longitudinal axes L12, L13.

The tangents T22', T23' at the track centre lines M22, M23
form track angles ε_0 with a parallel line L' extending parallel
to the longitudinal axes L12, L13, wherein, in the first case,
said tangents T22', T23' forming said track angles which are
positioned in the drawing plane and, in a special case, are
inclined at the angles φ_0, φ_0' relative to the illustration
plane.

Figures 2a and 2b will be described jointly below. They show
an inventive joint in the form of a twin ball joint, with
identical details having been given the same reference numbers
as in Figure 1. To that extent reference is made to the de-
scription of same. It can be seen that the ball tracks 22_1, 23_1
and 22_2, 23_2 of two adjoining balls 14_1, 14_2 held in a common
cage window 17 are designed so as to correspond to one another
according to sectional planes A-A and B-B. The identifiable
corresponding track extensions apply to all ball tracks of the

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joint. Joints of this type are referred to by the applicant as twin ball joints. In the scale shown, the details of the track cross-sections cannot be identified.

The individual illustrations of Figure 3 will be described jointly below. They show an inventive joint in the form of a counter track joint. Identical details have been given the same reference numbers as in Figure 1. To that extent, reference is made to the description of same. As can be seen with reference to the individual sections, the ball tracks 22_1, 23_1 of first balls 14_1 which, together with second balls 14_2, are held in a common cage window 17 comprise a first opening angle α_1 relative to the joint aperture and the second ball tracks 22_2, 23_2 of said second balls 14_2 which, together with the first balls 14_1, are held in a common cage window, comprise a second opening angle α_2 which opens towards the joint base.

The conditions shown here for the ball tracks of a pair of tracks apply accordingly to all pairs of tracks of two adjoining balls which are held in a common cage window. The first and second pairs of tracks alternate around the circumference. Joints of the type described here are referred to by the applicant as counter track joints.

The illustrations of Figure 4 will be described jointly below. As regards the details shown in Figure 4, reference is made to the description of Figure 1. Figure 4a shows a sectional line A-A which extends through two ball centres K1, K2 of the balls 14_1, 14_2 of two adjoining pairs of tracks and parallel to the longitudinal axes L12, L13. Figure 4b shows that the centre lines M22 of the outer ball tracks 22_1, 22_2 are positioned in planes E1, E2 which, together with the longitudinal axis L12, form an angle γ_0, whereas the centre lines M23 of the inner ball tracks 23_1, 23_2 are positioned in planes which extend par-

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allel relative to one another and which, together with the
longitudinal axis L13, form an identically sized angle γ_0' ope-
ning in the opposite direction.

Figure 5, in a cross-sectional view, shows two adjoining pairs
of tracks 22_1, 23_1; 22_2, 23_2 of two balls 14_1, 14_2 held in one
cage window 17. The cross-sectional shape of the ball tracks
is symmetrical relative to the radial rays RS1, RS2 which are
identical to the axes of symmetry ES1, ES2 of the track cross-
section. The ball centre lines are positioned in the panes E1
and E2 which extend parallel to the radial planes R1. The
cross-sectional shape of each ball track can be parabolic or
Gothic (composed of two circular arches with offset centres),
with two-point contact occurring in each of the ball tracks.
Irrespective of the position of the articulated joint, there
is ensured an advantageous force application angle of the pre-
viously mentioned pairs of force FR, which force application
angle does not substantially change during the articulation of
the joint, so that the balls cannot move towards the track
edges.

Figure 6, in a cross-sectional view, shows two adjoining pairs
of tracks 22_1, 23_1; 22_2, 23_2 of two balls 14_1, 14_2 held in one
cage window 17. In this case, too, the ball tracks of the
pairs of tracks 22_1, 23_1; 22_3, 23_2 are symmetrical relative to
the radial rays RS1, RS2 which are identical to the axes of
symmetry ES1, ES2 of the track cross-sections. The ball track
centre lines are positioned in the planes E1,E2 which extend
parallel to the radial planes R1. The cross-sections of the
ball tracks of each pair of tracks are formed by circular
arches whose centres M1a, M1i; M2a, M2i are positioned on the
respective radial ray RS1, RS2, with the radii Ra, Ri being
clearly greater than the ball radius. Torque-free conditions
thus result in contact between the balls 14_1, 14_2 and the ball

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tracks 22_1, 23_1; 22_2, 23_2 in the respective track base.

The illustrations of Figure 7 will be described jointly below. Identical details have been given the same reference numbers as in Figure 1. To that extent, reference is made to the preceding description.

In Figure 7a, the pitch circle radius PCR is split in accordance with its two components of PCRx and PCRy with reference to the x-axis perpendicularly relative to the sectional plane B-B and to the y-axis parallel to the sectional plane B-B.

Figure 7b shows the movement of the ball 14_2 when the inner joint part 13 is articulated relative to the outer joint part towards the left by an angle β, with the ball, with reference to the centre M, having been displaced by an angle $\beta/2$ relative to the outer joint part. There are also shown the pitch circle radii $PCRy(0)$ in an aligned joint and $PCRy(\beta/2)$ in a joint articulated by the angle β. Because of the way in which the track extends, $PCRy(\beta/2)$ is greater than $PCRy(0)$.

Thus, for the non-articulated joint, the following is obtained:

$$PCR_0 = \sqrt{(PCRx_0^2 + PCRy_0^2)}$$

and a pitch angle φ_0, with the pitch angle φ being calculated from

$$\tan \varphi_0 = PCRx_0 / PCRy_0$$

and for the articulated joint accordingly

$$PCR = \sqrt{(PCRx^2 + PCRy^2)}$$

and a pitch angle φ, with the pitch angle φ being calculated from

$$\tan\varphi = PCRx/ PCRy.$$

As PCR and φ change only slightly along the ball tracks, even tracks which are produced with a constant angle φ_R relative to the longitudinal planes through the radial rays R1 feature the advantageous introduction of force into the ball tracks as proposed by the invention.

Depending on the rotational position of the joint as a function of the angle of articulation, the ball is in different positions along the ball track. On condition that the ball tracks are positioned in planes extending parallel relative to one another and parallel to the longitudinal axis L12, L13, PCRx remains unchanged, whereas PCRy can vary. As a result, there occurs a slight change in the angle φ between the centre plane through the longitudinal axes L12, L13 and the through the y-axis, and the radial ray RS from the joint centre M through the ball centre K.

In order to accurately maintain the inventive symmetry of the ball tracks, the centres of curvature M1i and M1a and M21 and M2a respectively have to be positioned in planes formed by the radial rays RS1, RS2 and the longitudinal axes L12, L13.

Therefore, in accordance with the embodiment shown here, the centres M1i and M1a are each positioned in a plane which extends parallel to those planes which contain the track centre lines. This means that the effective line (axis of symmetry of the track cross-section) will no longer, in every position, extend accurately through the joint centre M, but through a centre M'. The deviation a between the two planes is rela-

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tively small. It is calculated as follows:

$$a = (PCRy(\beta) - PCRy(0)) \times \sin\varphi_0,$$

and the deviation of the plane of symmetry of the ball track cross-section towards the radial ray amounts to

$$\Delta\delta \approx a/PCR \text{[rad.]}.$$

In Figure 8, any details identical to those shown in Figure 4 have been given the same reference numbers, and the effect of the ball movement on the ball 14_1 when the joint is articulated as illustrated in Figure 7a has been taken over. Whereas the centre lines of the ball tracks always extend in the planes E1, E2, there occurs a displacement of the planes of symmetry of those track cross-sections which are no longer defined by the second radial rays RS1, RS2 intersecting one another in the joint centre M, but by the axes of symmetry ES_1, ES_2 intersecting one another in the point M' in the radial plane R1. The track centre $M1_0$ is displaced in the plane E1 into the track centre M1. A radial ray from the joint centre M and, respectively from the longitudinal axis through the track centre deviates from the radial ray RS1 by the angle $\Delta\delta$. The distance between the centres M, M' and $M1_0$, M_1 is given as $\Delta PCRy$.

Figure 9 gives the angle conditions of Figure 8 in the form of an enlarged detail.